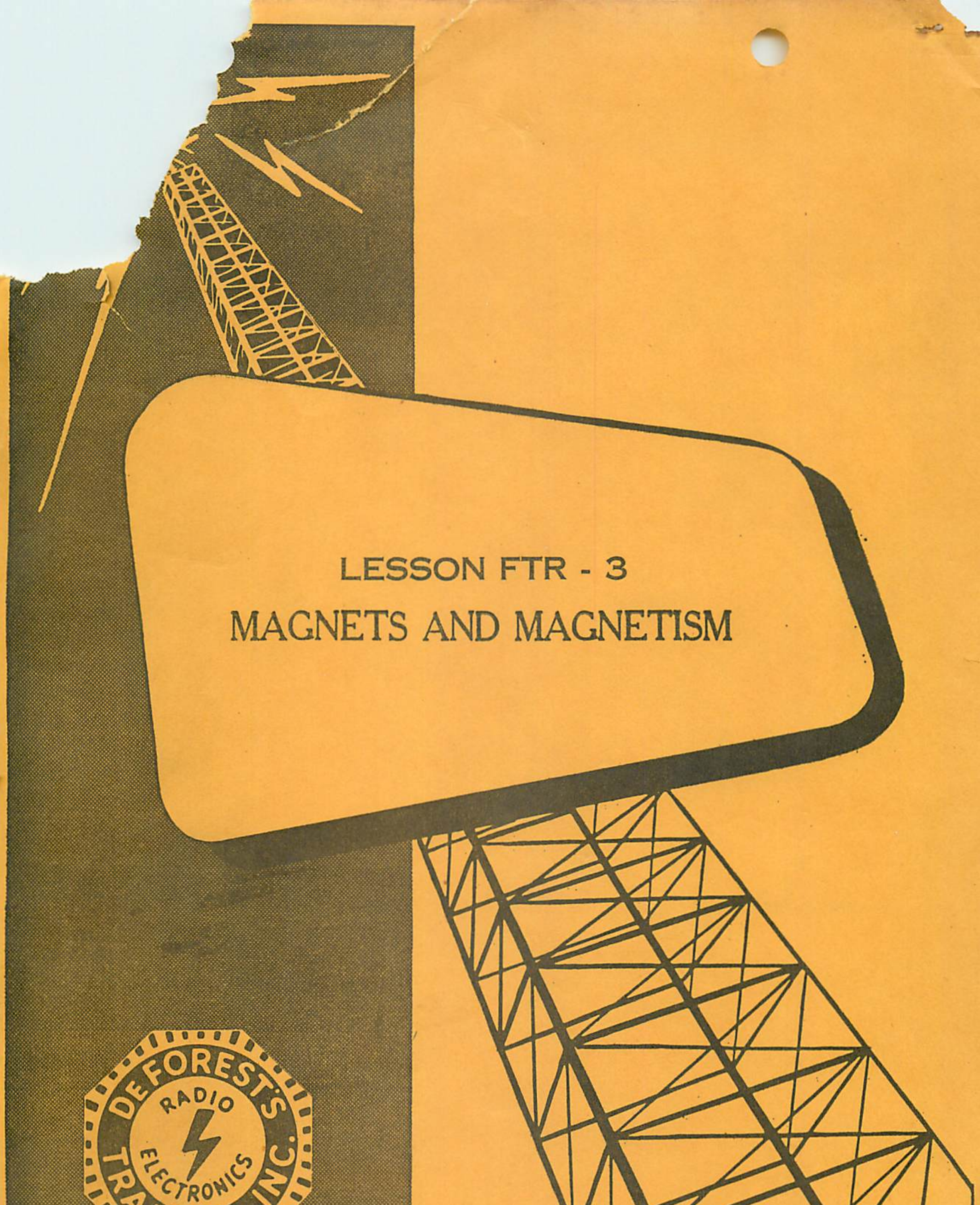

LESSON FTR - 3

MAGNETS AND MAGNETISM

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LESSON FTR-3

MAGNETS AND MAGNETISM

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RESOLVE:
To cultivate a cheerful spirit, a smiling confidence and a soothing voice. The sweet smile, the subdued speech, the hopeful mind, are earth's most potent conquerors, and he who cultivates them becomes a very master among men.

-- Hubbard

MAGNETISM

As many of the component parts, used in Radio apparatus, depend upon magnetism as well as electricity in order to provide proper operation, we are going to delay our explanations of electricity long enough to give you an idea of magnetism.

You will understand why this is an important subject when we tell you that, in Radio, Sound and Television equipment, none of the coils, chokes, transformers or common types of speakers could work without magnetism in some form.

Laten on, when we explain these different parts in detail, you will need a knowledge of magnetism to understand their action therefore, by learning the general principles now, you will save time as you advance.

NATURAL MAGNETS

History tells us that the ancient Greeks knew of a certain kind of stone which had the strange power of attracting pieces of iron. They are also credited with the discovery that when a piece of iron had been rubbed on one of these stones, it then had the power to attract other pieces of iron.

It was also discovered that when one of these stones was hung on a string, so that it could turn easily, it would always come to rest when pointing in a North and South direction. This was most important because the stones could be used for "leading", in places where directions were not known and thus they came to be called "Leadstones" or "Lodestones".

Today, we know the Lodestone is merely a natural magnet and its action is still in use but we call our modern Lodestone a Magnetic Compass. Every ship on the ocean uses a compass of some sort to show the proper directions when out of sight of land. Hunters and Fishermen usually take a compass along when they go into the woods, or other strange country, where there are but few roads or houses.

MAGNETIC SUBSTANCES

Like Electricity, the exact nature of magnetism is not known but, a careful and thorough study of magnets and their actions show that all materials are affected to some extent, when brought close to a strong magnet.

Trying all of the known substances, it has been found that iron and steel are affected very strongly, cobalt and nickel to a lesser extent while the effect on all the rest is very slight. The difference is so marked that iron and steel are commonly classed as "Magnetic Substances".

By themselves, cobalt and nickel are not commercially important but, when alloyed with steel, form substances with magnetic qualities superior to those of iron and steel alone.

ARTIFICIAL MAGNETS

Permanent &

When a piece of steel is rubbed on a magnet or lodestone, it becomes a strong magnet itself and, by the proper treatment which we will explain later, can be made to keep its magnetism almost indefinitely. For this reason, a piece of steel, when properly magnetized and treated, is called a "Permanent Magnet".

Tempora magnets

Iron, on the other hand, especially soft iron, when rubbed on a permanent magnet or a lodestone, becomes magnetized just as strongly as the piece of steel. However, when the magnet is removed, the iron at once loses practically all of its magnetism and therefore we think of the soft iron as a "Temporary Magnet".

MAGNET POLES

Suppose now that we take a small bar of magnetized steel and by tying a string around it in the middle, so that it will balance as in Figure 1, hang it up and let it turn freely. No matter which way we point it, when we let it go, it turns and swings back and forth but always stops when pointing north and south. This action we will explain now by saying that the earth itself is a huge magnet which is attracting the magnetized steel bar.

The end of the steel bar magnet that points toward the North, is called the "North Seeking Pole" and the end that points toward the South, is called the "South Seeking Pole". While the end of a magnet is usually spoken of as a pole, it really is at that point which has the greater power of attracting iron or steel. Whenever you see a permanent magnet with the ends marked "N" and "S", remember that the "N" is the north seeking pole and the other, or the "S", is the south seeking pole. It is the general custom to speak of them as north and south poles.

MAGNETIC LINES OF FORCE

You have, no doubt, at some time in your life, played with a little toy horse-shoe magnet as shown in Figure 2, and perhaps you were surprised at some of the things it would do. Did you ever notice that a real small piece of iron would actually jump a quarter of an inch or more to reach the magnet?

The fact that the iron jumps up to the magnet shows very clearly that the action of the magnet extends out and around it. You can think of this magnetic force somewhat in the same way as you think of a current of electricity, except that the "current" of magnetism is called "Magnetic Lines of Force".

MAGNETIC FIELDS

In Figure 3, we have a bar of magnetized steel and have shown, by light broken lines, the path of these lines of force through the air around the magnet. They travel at the same speed as electricity and are always thought of as coming out of the "N" pole and going in at the "S" pole. Each line, when fully drawn, forms a complete loop from "N" to "S" outside the magnet, and from "S" to "N" inside.

The space outside the magnet, through which these lines pass, is called the MAGNETIC FIELD.

You can very easily prove this action to yourself and to make a magnetic field like that of Figure 3, place a piece of ordinary window glass over a bar magnet and then sprinkle iron filings on the glass. You will find that the filings arrange themselves in lines just like our Figure.

Of course, the finer the filings, the more uniform your lines will be and, if you use coarser pieces, you may have to tap the glass gently to help the filings arrange themselves.

In thinking of these magnetic lines, just imagine that they are very small rubber bands stretched real tight. You know that under these conditions, the rubber will try and shorten itself, and that is exactly what the magnetic lines try and do. They also crowd each other somewhat and try and push sideways.

MAGNETIC FLUX

As our work has very little to do with the separate magnetic lines, we usually consider all the lines in a magnetic field as one group which we call the "Flux". The total number of magnetic lines passing through any given area is known as the "Magnetic Flux".

REPULSION OF MAGNETIC POLES

Figure 1, shows the magnet, mentioned earlier in the Lesson, tied up with a string and marked with an "N" on the end that points north and an "S" on the end which points south. Now, to find out just how two magnets act toward each other, we will use a second magnet, marked the same way.

To begin, we hold the second magnet in our hand with the "N" end out, as in Figure 4, and bring it slowly up to the "N" pole of the magnet hanging on the string. We find, that as the two "N" poles get close to each other, the magnet hanging on the string turns away from the magnet in our hand. It looks just as though the magnet in our hand was actually touching and pushing the magnet on the string. We can easily see however, that the magnets do not touch, and therefore decide that it is the magnetic force which does the pushing.

ATTRACTION OF MAGNET POLES

Next, we turn the magnet in our hand so that the "S" pole is out, as in Figure 5, and again bring it slowly toward the magnet on the string. Now we find that the "N" pole of the hanging magnet turns toward the "S" pole in our hand, and will, when we get close enough, swing over until the magnets touch.

ONE LAW OF MAGNETIC FORCE

When we move the "S" pole of our magnet toward the "S" pole of the magnet on the string, it turns away exactly as it did when the "N" poles were brought close together.

These simple tests prove one of the most important laws of magnetism which is — Like poles of a magnet repel each other and unlike poles attract each other.

MAKING MAGNETIC FIELDS

There is another way to demonstrate this same action, and while it takes a little more time, it is well worth while. Two permanent magnets are placed on a table or board, in fact any flat surface except iron will do, with their ends about an inch apart, as in Figure 6, and with both "N" poles pointing toward each other. A piece of glass is laid over the magnets and iron filings are sprinkled on the glass. By tapping the glass gently, the filings arrange themselves in lines that curve away from the end of each magnet, while the space in the center has practically no lines in it at all.

By turning one of the magnets around, as in Figure 7, and bringing an "N" and "S" pole together, when the filings are again sprinkled on the glass, they arrange themselves in almost straight lines right across the gap between the "N" and "S" poles.

We want you to think of these magnetic lines as always forming a complete circuit, just like an electrical circuit, except that they will pass through every known substance and travel from the "N" pole, out around to the "S" pole and then back through the magnet to the "N" pole again. With this in mind, in Figure 6 you can see that the magnetic lines of each magnet turn around toward their own "S" pole and have nothing to do with those of the other magnet. In fact, it looks as if they were trying to crowd each other out of the way. In Figure 7 however, the lines go straight across from the "N" pole of one magnet to the "S" pole of the other and the magnetic circuit is completed through both of the magnets.

LOCATION OF MAGNET POLES

Going back to Figure 3 for a minute, you will notice that the lines of magnetism form complete loops all of which come very close together at a point near each end. These points are the real poles of the magnet. Experiments have shown that the pull of the magnet on a piece of iron will vary with the number of magnetic lines passing through it. As the lines are the closest at the poles, it stands to reason that the closer we move a piece of iron to the pole, the more magnetic lines there will be passing through it, and therefore the stronger the pull will be.

ANOTHER LAW OF MAGNETIC FORCE

Also in Figure 3, you will notice that as the lines leave the poles, they spread out in all directions and should you move a piece of iron further away from the pole, there would be fewer lines passing through it and the pull on it would be less. This reduction in pull changes very fast and Figure 8 shows you the reason. Here we have taken all of the magnetic lines coming out of the center of the end of a magnet and find that when we are one inch away, they all pass through a piece of iron one inch square.

Moving the iron away another inch, that is, putting it two inches away from the magnet, we see that it would take a piece two inches square in order to have all of the lines pass through it. Now, as it takes four one inch squares of iron to make a piece two inches square, if our first one inch square of iron were held two inches away from the magnet only one quarter of the magnetic lines would pass through it. If there were but one quarter of the magnetic lines through the iron, there would be but one quarter of the magnetic pull.

Notice here that twice the distance gives but one fourth the pull and, in the same way, three times the distance will give but one ninth the pull, four times the distance one sixteenth the pull and so on.

This change follows a very definite rule. For example, from the values above, 2 times the distance gave us one fourth the pull. Now 2 times 2 equals 4, and if we turn 4 over we get one fourth. In the same way, 3 times 3 equals 9, which turned over, or "inverted", is one ninth. Whenever we multiply a number by itself, we say that the number is squared. As the distance gets smaller, the pull gets stronger, at a rate equal to the square of the distance. We say therefore, that the pull varies opposite to, or inversely as, the square of the distance.

As a general rule we can state -- "The field of a magnet at any point, varies inversely as the square of the distance from the pole to the point".

INDUCED MAGNETISM

Another thing we find is that when a piece of iron, such as a tack, is hung on the end of a magnet, it also becomes magnetized and will attract and hold a second tack. If the magnet is strong enough, we can build quite a string of tacks in this way. No matter how carefully we take the magnet away from the first tack, as soon as it is removed, the tacks all fall apart. This is because, being made of iron, the tacks are but temporary magnets and will not retain the magnetism. Whenever a piece of iron or steel is made to act as a magnet by being held in contact with a magnet, we call the action "Induced Magnetism".

THEORY OF MAGNETISM

As we said at the beginning of this Lesson, no one knows the exact nature of magnetism but its actions can be explained by what is called the Molecular Theory. This theory explains that all metals are made up of very small particles, called molecules, each of which is in itself an extremely small magnet. In iron and steel the molecules are much stronger magnets than in any of the other metals.

In the ordinary piece of iron or steel, these molecules are not arranged in any particular order and their magnetic fields are all neutralized as in Figure 9.

PERMEABILITY

Whenever the iron or steel is put in a strong magnetic field, as unlike poles attract each other, the molecules all turn in one direction, like Figure 10, the magnetic fields of all of them combine and make the entire piece of metal into one large magnet.

It depends on the kind of metal, as to how easily the molecules can be turned. In soft iron they turn quite easily, but, as soon as soon as the magnet that attracts them is removed they turn back to their original position just about as easily. This accounts for the fact that soft iron will not hold its induced magnetism and is called "Temporary Magnet."

However, the ease with which the molecules can be turned determines the strength of the magnetic flux that will be produced by the magnetizing force. The ratio of the produced flux to the magnetizing force is known as the permeability of a material. In general, you can think of permeability of a substance as its ease in carrying magnetic flux.

In the case of steel it is much harder to turn the molecules all in the same direction and therefore requires a stronger magnet. Once they are all turned the same way, they stay in that position after the magnet that attracted them has been removed, and the steel retains its magnetism.

This is the reason why all permanent magnets must be made of steel and the action is called "Retentivity." From the explanation just given, you can see that every time a permanent magnet is jarred the molecules will have a tendency to turn back to their original position and thus weaken the strength of the magnet. Heating the magnet will have a similar weakening effect.

FORMS OF MAGNETS

All the magnets we have mentioned have been of a horse-shoe or straight bar type, but a solid ring of iron or steel can also be strongly magnetized. As the ring is solid, very few magnetic lines come outside and there are no poles. However, if we cut out a section of the ring at any point, we find a very strong magnetic field in the break with an "N" pole at one side and an "S" pole at the other.

As far as anyone knows, magnetic lines will pass through any material. In making up the magnetic fields with iron filings in the earlier part of this Lesson, we put the magnet under a piece of glass and sprinkled the filings on top. Those materials used as electrical insulators have no more effect toward insulating magnetism than the air itself. Remember in this connection however that the air and all materials except iron, steel and a few alloys, offer a high resistance to the lines of magnetic force.

MAGNETIC SCREENS

When we want to prevent magnetism from passing through any object, such as a watch for example, the only thing we can do is to put a piece of iron around it. Iron, being a magnetic substance, carries the magnetic lines so much easier than air or other materials that, instead of passing through the watch, they will pass around it through the iron. We call this a Magnetic Screen. Looking at Figure 11, you can see what happens and will notice that the space inside the iron shield has no magnetic lines passing through it.

DISTORTION

Instead of the shield of Figure 11, in Figure 12, we have placed a piece of soft iron in the field of a permanent magnet. The magnetic lines are pulled around so that a great many of them pass through the iron. With all these lines through it, the iron becomes a magnet and has poles of its own. As unlike poles attract, it can be seen how the poles of the piece of iron attract the opposite poles of the permanent magnet and thus pull the magnetic field out of its natural shape. This action is called "Distortion" and whenever a magnetic field is pulled out of shape by the presence of iron, or another magnet, we say that the field is distorted.

MEASURING MAGNETIC FLUX

In the use and measure of magnetic fields, it has been agreed that a certain amount of magnetism represents one line of force. In practical work, the Flux has a comparatively large number of lines and the fields are of all sorts of shapes and sizes.

You will usually hear magnetic fields spoken of as having so many lines of force per square inch. This means the number of lines that will pass through each square inch of any material that is placed square across the magnetic field.

THE MAXWELL

In many books and articles you will find the term "Maxwell" used in connection with magnetic fields, but it is simply a unit of measure and one Maxwell is equal to one line of force.

THE GAUSS

When the strength of the flux is measured in Maxwells and the field area is measured in square centimeters, then the density of flux, which is the number of lines per square centimeter, is often spoken of as so many maxwells per square centimeter.

One maxwell per square centimeter is sometimes called a Gauss. Thus a magnetic field with a density of 10,000 gausses simply means a magnetic field with 10,000 lines of force per square centimeter.

MAKING PERMANENT MAGNETS

As we have already mentioned, a permanent magnet can be made by rubbing a piece of steel on another magnet but this method does not make a magnet strong enough for practical use. In all commercial work, permanent magnets are made by placing a piece of steel in a very strong magnetic field which is produced by electricity.

AGEING MAGNETS

In order to keep the greatest amount of magnetism for the longest time, the steel of the magnet is hardened and then aged. One method of ageing the steel is to heat treat it for a long period after it is hardened. Then after it is magnetized as strongly as possible, it is given another heat treatment. This second heating, or ageing, weakens the magnetism to some extent but what is left is almost permanent.

TESTING MAGNETS

A very simple method of testing the strength of a permanent magnet is to place a bar of iron across its poles and then, by using a scale, see how many pounds pull is required to remove the piece of iron.

There are also testing meters which are placed across the poles of the magnet to be tested, and their action is very similar to the method explained above except the flux of the magnet pulls a pointer across a marked scale.

Permanent magnets are used in a great variety of Radio, Sound and Television apparatus as you will learn in your study of the later Lessons. They are made in many different shapes but the most common are the straight bar and the "U" or horse-shoe.

While all magnetic speakers and headphones have permanent magnets, many of the other units operate by magnetism and in many respects, it is as important as electricity.

As we mentioned above, permanent magnets are made commercially by being placed in a very strong magnetic field produced by electricity. Therefore, to continue our explanations, we are going to tell you how a current of electricity can be made to produce a magnetic field or flux.

ELECTRO MAGNETS

The discovery of Electromagnetism occurred over 100 years ago when, in 1820, Professor Oersted found the electric current of a battery, when made to pass through a wire, acted on a compass needle placed below the wire. To follow the experiments of these early investigations, for Figure 13 we show a piece of wire, pushed through the center of a square of cardboard. The wire is a part of a simple electrical circuit which contains two dry cells as a source of voltage.

As soon as this circuit is completed, there will be an electrical current from the center terminal of the left cell, up, over and down through the wire and back to the outside connection of the right hand cell. The circuit is completed through the cells and the connecting wire between them.

We now place a magnetic compass on the cardboard and move it all around the wire. It no longer points North, but keeps changing its position, as we move it around in a circle. When we remember that the moving part of the compass is a permanent magnet and has an "N" and "S" pole, the very fact that it changes position as we move it around the wire, proves that there is some magnetic action set up by the current in the wire.

As soon as the circuit is opened, there is no current in the wire and the compass points North no matter how close we place it or what position we put it around the wire. The instant the circuit is closed however, the current in the wire immediately sets up the magnetic action and pulls the compass needle around. It is thus very easy to see it is the current and not the wire that sets up the magnetic action.

ACTION OF THE COMPASS IN A MAGNETIC FIELD

Thinking back for a minute to the laws of magnets, we know that if the magnetized needle of the compass is placed in a magnetic field, its "N" pole will try to turn away from the other "N" pole, while its "S" pole will try to turn towards the other "N" pole. The same effect will take place at the "S" pole, but in the opposite direction, to provide a double action, a pull on one end and a push on the other. This double action will make the compass needle turn until it is lined up with the magnetio lines of the flux in which it is placed.

Now, looking at Figure 13 again, when we move the compass around the wire, the needle points out a circle, thus there must be a circular magnetic field around the wire. Raising or lowering the cardboard on the wire has no effect on the compass action and it still points around in a circle as we move it around the wire.

MAGNETIC FIELD AROUND A WIRE

We want you to think of this magnetic field around a straight wire just as though you have a lot of cardboard disks on a string like Figure 14. Of course, the magnetic field is not in flat disks like the cardboard, but is exactly the same all along the wire. Magnetism, however, is always in motion and travels at the same speed as electricity, so that you can think of this magnetic field as spinning around the wire.

It is just the same as though the cardboard disks of Figure 14, were spinning around on the string. In Figure 13 then, there is a magnetic field whirling around and round the wire as long as it carries current.

DIRECTION OF MAGNETIC FIELD

To experiment further, suppose we now change the connections to the dry cells of Figure 13, that is, connect the bottom of the wire to the center of the left hand cell and the top end to the outside of the right hand cell. Putting the compass on the cardboard now, we find that it still points in a circle, when moved around the wire but points in the opposite direction.

In a later Lesson on Dry Cells, we will give you a complete explanation of the reasons why we always consider the current or electricity comes out of the center connection and goes back in at the side connection therefore ask that you take our word for it at this time.

In Figure 13, when the current is down through the wire in the cardboard, the compass needle points around in a clockwise direction. When we change the dry cell connections, the direction of current is up through the wire and the compass needle turns around and points in an anti-clockwise direction.

THUMB RULE ✓

After watching these actions we know that there is a definite relation between the direction of electrical current and the direction of the magnetic field. We find that these directions are in the same relation to each other as the thumb and fingers of our right hand.

To make use of this fact, we can take hold of the wire, as in Figure 15, with our thumb pointing in the direction of the electrical current and our fingers then go around the wire in the same direction as the magnetic flux. This is the "Thumb Rule" but, when you use it, remember that it is always a good plan to play safe and instead of actually taking hold of the wire, just place your hand in the proper position along side of it.

You will find this simple rule very useful because, if you know the direction of current, you can find the direction of the magnetic field or, should you know the direction of the magnetic field, you can find the direction of the electrical current.

There is not much to the thumb rule, is there? It really looks so easy that you are wondering what good it will do you. Well, just take our word for it, until you find out for yourself, that all of the rules we are going to give you are just as easy as this one, once you understand them.

It is knowing a few easy rules like this that makes Radio Communication work seem simple but, if you don't know them, you can never advance very far.

MAGNETIC FIELD AROUND A LOOP

To experiment further, we take the wire of Figure 13 out of the cardboard and bend it in a loop like Figure 16. Using the thumb rule here, we find that with current in the direction shown by the arrows, our fingers will point toward the inside of the loop no matter on which part we place our hand. With all the magnetic lines going in one and the same direction inside the loop, and the opposite direction outside, the magnetic field as a whole must be very much like that set up by a permanent magnet.

MAGNETIC FIELD AROUND A COIL

Following this idea a little further, we now bend the wire into several loops, or a coil, like Figure 17. Connecting this wire in an electrical circuit and sending current in the direction of the large arrows, we again take a magnetic compass and move it both inside and outside of the coil.

By watching the action of the compass we find that the magnetic lines, instead of whirling around each coil of the wires, all seem to join and form one magnetic field whose direction is as shown by the broken lines. This flux, you will notice, is exactly the same as that set up by a permanent magnet and the "N" pole, in this case, would be at the upper end where the compass shows the lines coming out.

P

As long as there is current in this coil, it acts exactly like a permanent magnet. It has "N" and "S" poles and, if free to turn, will point north and south. The big difference between this coil and a permanent magnet is that the instant there is no current in it, there is no magnetic field around it, and the more current there is in the wire, the stronger the magnetic flux will be.

RIGHT HAND RULE

Like the straight wire of Figure 13, there is a definite relation between the direction of electrical current and direction of magnetic flux in the coil of Figure 17. In this case, we again use our right hand, as in Figure 18, with the fingers pointing around the coil in the direction of the current and our thumb will then point toward the "N" pole.

This is called the "Right Hand Rule" and can be used whenever the wire is coiled and the direction of current and coils is the same through the entire length. Notice here, for the "Thumb Rule", the thumb points in the direction of current while, for the Right Hand Rule, the thumb points toward the "N" magnetic pole.

SOLENOIDS

In common practice, a coil like that of Figure 17 is called a Solenoid which, as long as there is current in it, has all the magnetic qualities of a permanent magnet. As we found in the single loop of wire, there must be an electrical current in the coil before a magnetic field is set up. Here again, an increase of current increases the strength of the magnetic flux and, in the same way, when the current is reduced, the magnetic flux is weakened.

AMPERE TURNS

Should we now increase the number of loops, or turns, of the solenoid, and keep the current the same, the strength of the magnetic field would also increase. You can easily understand the reason for this when you remember that each loop of the solenoid sets up its own magnetic field, which unites with those of the other loops. The more loops there are in the solenoid, the more magnetic fields there will be to unite, therefore the main magnetic field will be stronger.

To compare the magnetic strength of different solenoids, and have a unit for measuring them, we usually multiply the number of turns of wire by the number of amperes in the wire and call the answer Ampere-Turns.

For example, a solenoid with ten turns and a current of ten amperes will have one hundred ampere-turns. Another solenoid with 50 turns and a current of 2 amperes will also have 100 ampere-turns.

ACTION OF AN IRON CORE

From our explanation of Magnets, you know that iron and steel will carry magnetic lines of force much better than air or other materials and therefore, to increase the magnetic flux of a coil like that of Figure 17, we place a piece of iron inside it. This iron is called the Core and its action is to carry practically all of the magnetic lines. As iron carries the lines several hundred times easier than air, you can see there will be many more magnetic lines of force in the core than the air inside the coil could possibly carry. The complete assembly of a solenoid, with an iron core inside it, is called an Electro-Magnet.

MAGNETIC CIRCUITS

We want you to think of the different paths for magnetic lines of force in much the same way as we explained the electrical circuit. You remember in the electrical circuit there was a pressure, or E.M.F., that forced a current of electricity through a circuit that had resistance.

For a magnetic circuit we use exactly the same idea but do not have to build a special path because the magnetic lines will travel through anything. Their path, however will always be from the "N" to the "S" pole outside the magnet.

Instead of an E.M.F., for the magnetic circuit we have a Magnetomotive Force, M.M.F., which forces a Flux around a circuit that offers Reluctance.

Now don't let the word "reluctance" bother you because it is only that property of a magnetic circuit which opposes or tends to stop the passage of magnetic lines of force. In electric circuits, nearly all substances have different resistance properties, some offering little and others offering great opposition to the electric current. In magnetic circuits, nearly all substances, except magnetic metals, have practically the same Reluctance. Iron has relatively low reluctance while air and other nonmagnetic materials have the same and a relatively high reluctance.

Comparing the Magnetic Circuit with an Electrical Circuit, we have M.M.F. instead of E.M.F., Flux instead of Current and Reluctance instead of Resistance.

LAW OF MAGNETIC CIRCUITS

As a law for the magnetic circuit we can state: "The Flux of a magnetic circuit is equal to the M.M.F. divided by the Reluctance".

Although a piece of iron will carry magnetic lines several hundred times better than air, there is a limit to its ability. You might think of it as a blotter. When a blotter is new, it soaks up ink very readily and quickly but, after it has been used for a while and is pretty well ink soaked, it is very hard to make it soak up any more.

The iron core is very much the same. When there are but few magnetic lines through it, a small increase of M.M.F. will cause quite an increase in the number of lines. When there are a great many lines through it, a great increase of M.M.F. is required to cause much of an increase in the number of lines.

When a piece of magnetic material carries the greatest practical number of lines, it is said to be saturated. Of course, it is possible to still increase the magnetic flux but the M.M.F. required is so great, compared to the increase, that it is seldom done in practical work.

FORMS OF ELECTRO-MAGNETS

Electro-Magnets are used in many different ways, each of which we will explain fully in our later Lessons, therefore at this time we will just mention some of the most common ones.

Every electric motor and generator requires a very strong magnetic field to cause its action. With the exception of a very few small machines and special types, all have electro-magnets. Practically all headphones and many Loud Speakers have electromagnets and, by a change of electrical current in the magnet winding, the strength of the magnet varies, making the diaphragm vibrate so as to reproduce the voice or music.

Telegraph instruments use electro-magnets to attract a movable arm to cause the clicking noise by which messages are received.

Very large electro-magnets are mounted on cranes and hoists and used to lift large pieces of iron or steel. These magnets are so strong that they can hold several tons of metal and are used extensively in foundries, machine shops, and steel mills for loading and unloading cars or moving metal to various parts of the shop.

We could go on and give you many more uses of electro-magnets but, for this Lesson, all we want you to remember are these few simple facts.

Whenever a current of electricity is sent through a coil of wire, like Figures 17 and 18, the coil sets up a magnetic field and has all the properties of a permanent magnet.

The strength of the magnetic field varies with the number of turns and the amount of current but, with no current, there is no magnetism.

An iron core placed inside the coil greatly increases the strength of the magnetic field.

From the explanations of this Lesson, you can see that magnetism will be present around the wires of every electrical circuit which carries current. Therefore, for our next Lesson, we are going to explain the common sizes of wire, together with the types of insulation, that you will work with in the various Radio, Sound and Television circuits.

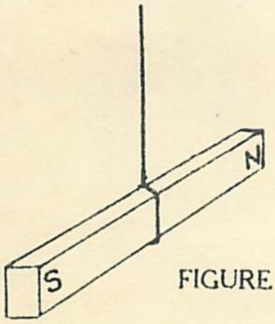
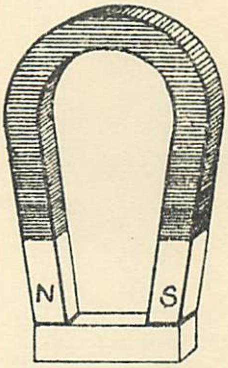
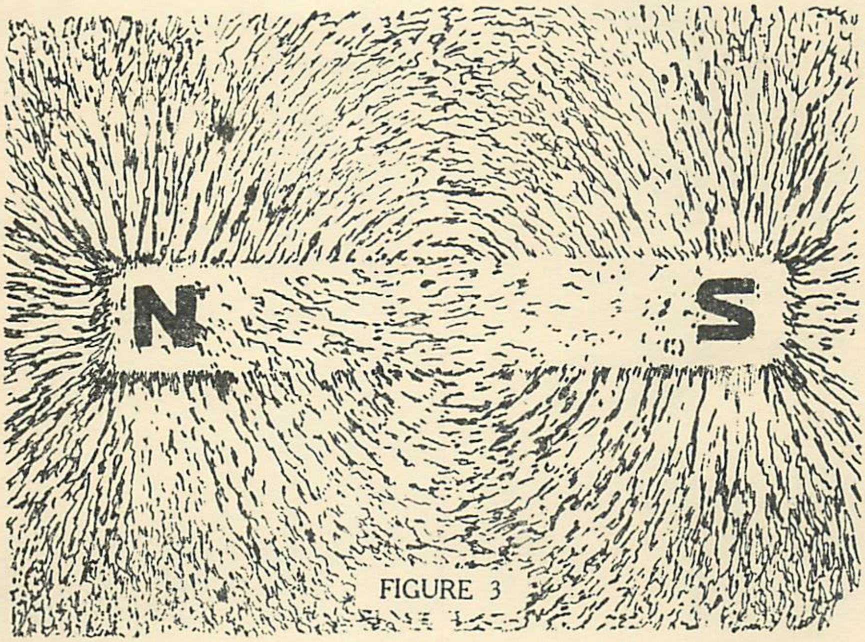


FIGURE 1



TOY MAGNET
FIGURE 2



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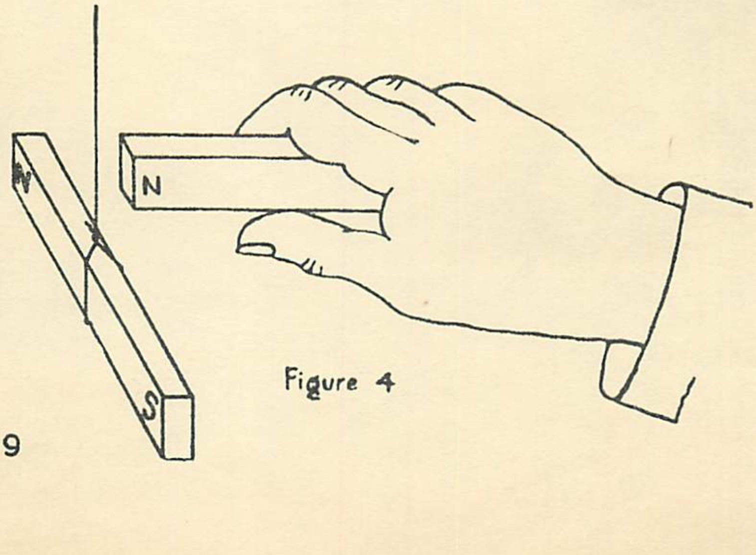


Figure 4

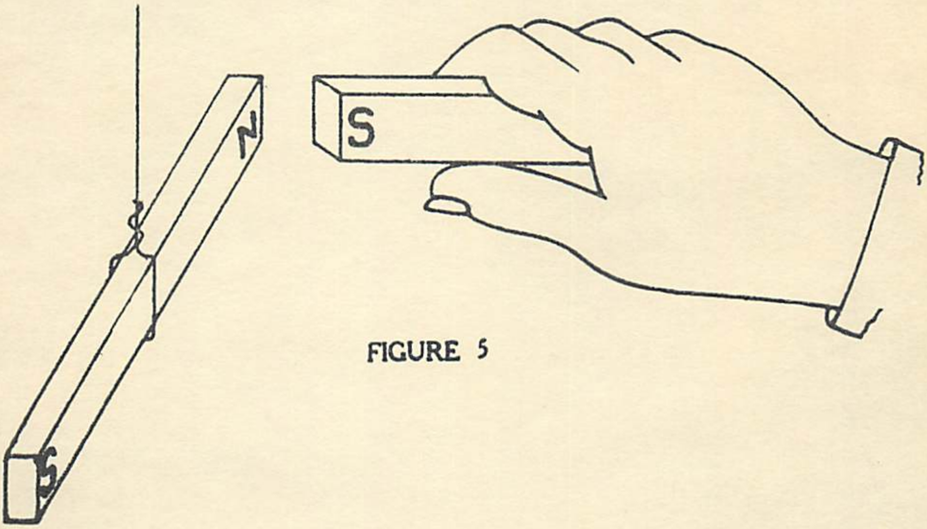


FIGURE 5

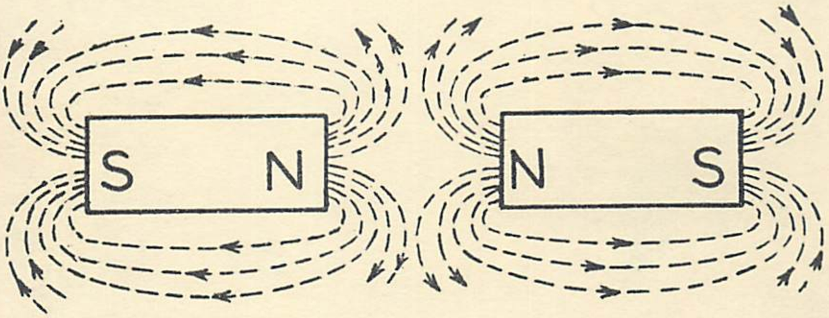


FIGURE 6

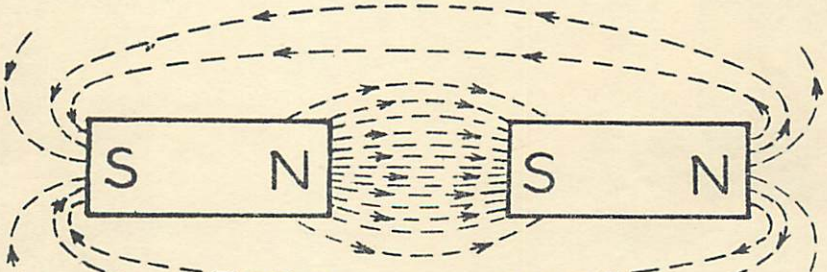


FIGURE 7

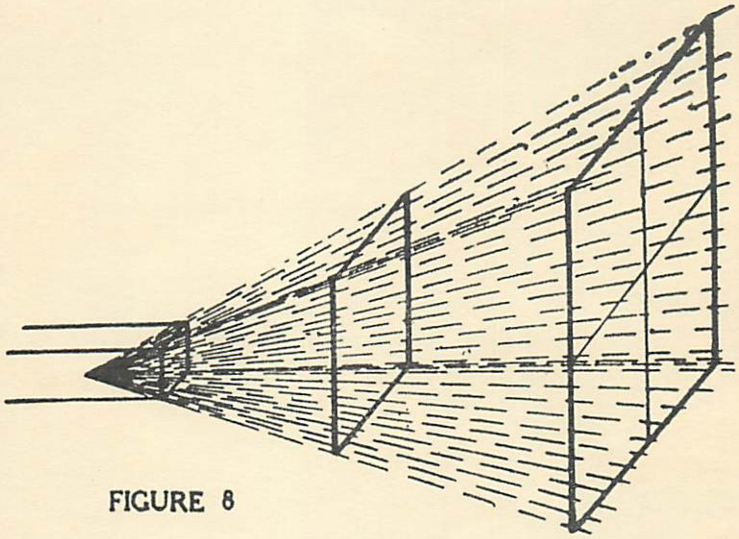
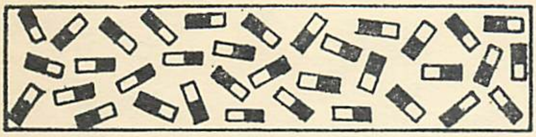


FIGURE 8



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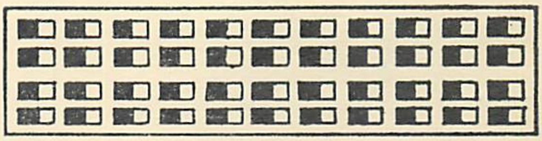

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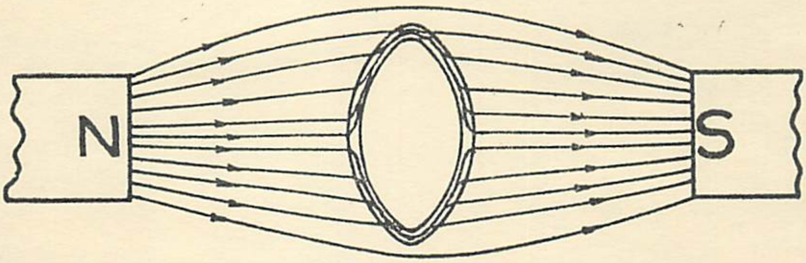

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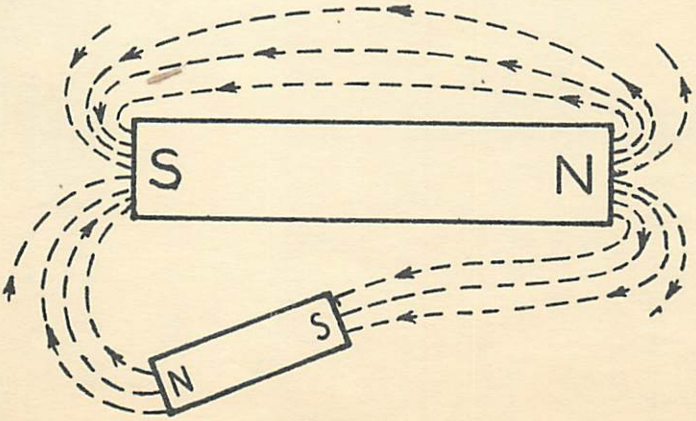

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FIGURE 12

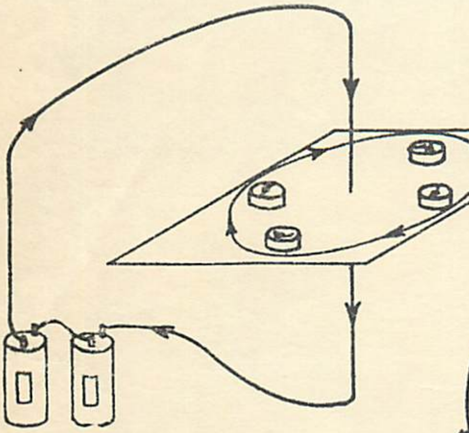

FIGURE 13

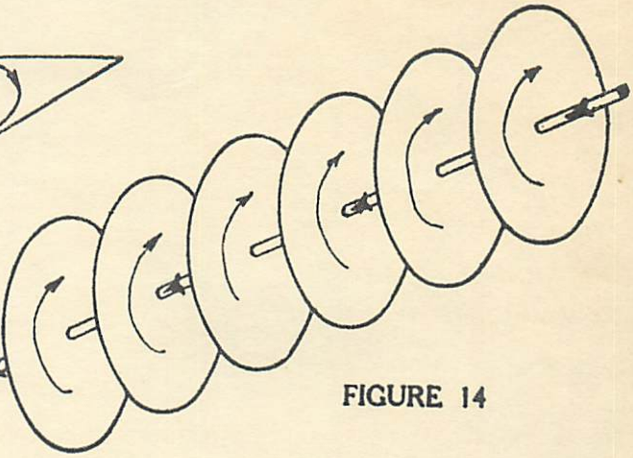

FIGURE 14

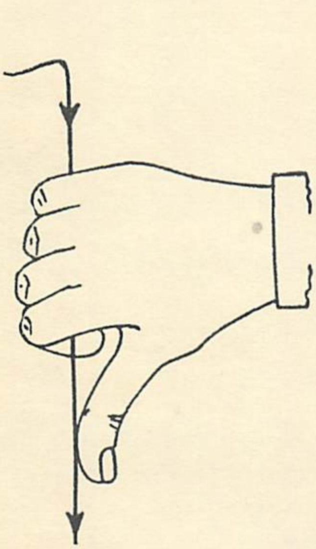

FIGURE 15

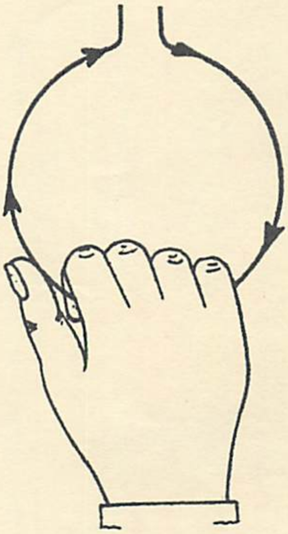

FIGURE 16

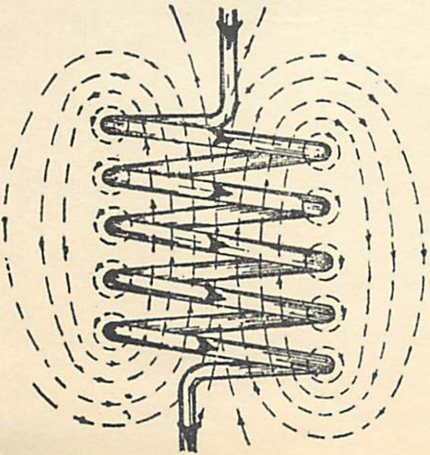

FIGURE 17

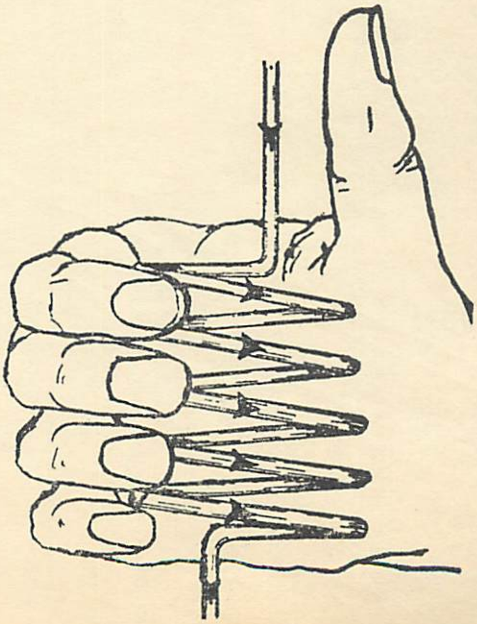

FIGURE 18

QUESTIONS AND ANSWERS

1. What are the common magnetic substances?
   The common magnetic substances are iron and steel.

2. What is the difference between a "Temporary" and a "Permanent" magnet?
   A temporary magnet retains its magnetism only while it is in the field of another magnet. A permanent magnet retains its magnetism without any help from other magnets.

3. What is meant by the "Poles" of a magnet?
   The poles of a magnet are those points on the magnet where the action is strongest.

4. What is a magnetic field?
   A magnetic field is that space around a magnet in which the lines of force travel. It extends as far as the magnetic action can be noticed.

5. How do unlike magnetic poles act toward each other?
   Unlike magnetic poles attract each other.

6. What happens around a wire when there is a current of electricity in it?
   A magnetic field is set up around a wire when there is a current of electricity in it.

7. How is the magnetic strength of a solenoid measured?
   The number of turns of wire is multiplied by the number of amperes in them. The result is Ampere-Turns which is the unit of measure.

8. What happens when an iron core is placed in a solenoid?
   The strength of the magnetic field is greatly increased when an iron core is placed in a solenoid.

9. What is meant by Reluctance?
   Reluctance is the name given to the resistance offered to the passage of magnetic lines of force.

10. What is the Law for the magnetic circuit?
    The Law for the magnetic circuit is: The flux is equal to the M.M.F. divided by the Reluctance.